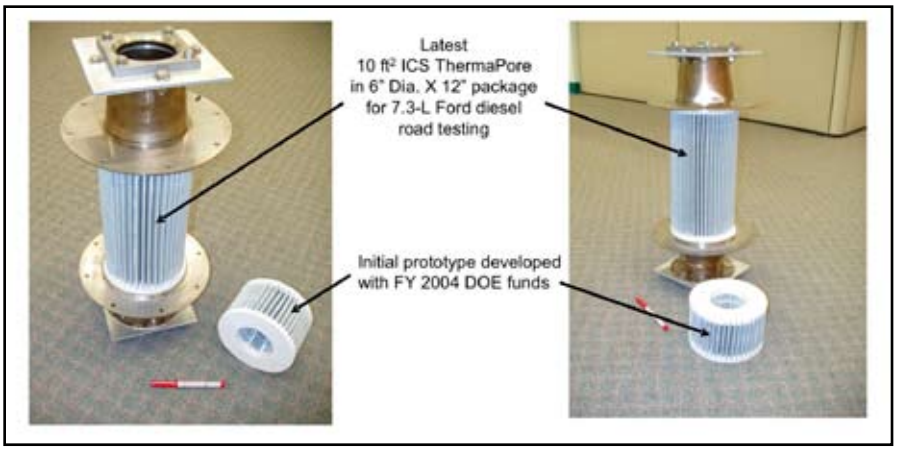
Self-Cleaning Diesel Particulate Filter

Background

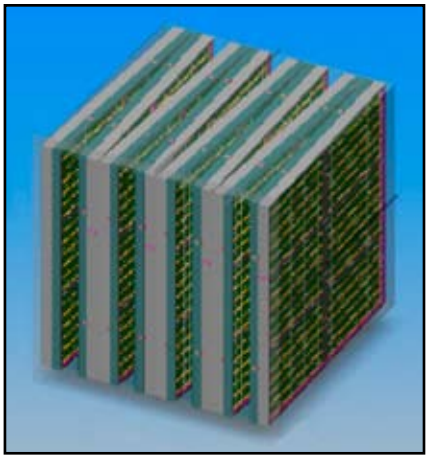
High-efficiency, advanced diesel engines are a leading near-term option for reducing petroleum consumption in the United States. Today's automotive and heavy-duty diesel engines convert about 40 to 45% of a gallon of diesel fuel to useful power, providing almost 40% better fuel economy than gasoline vehicles. However, diesel engines face serious challenges in meeting the Environmental Protection Agency's (EPA) 2007-2010 vehicle emissions standards for oxides of nitrogen (NO_X) and particulate matter (PM). For light-duty vehicles, new emission control systems must reduce engine-out emissions of NO_X and PM by 90%, to 0.02 grams/mile and 0.01 grams/mile, respectively. These reductions in NO_X and PM must be achieved while minimizing adverse effects on fuel economy.

Current diesel engine particulate filter technologies depend on a catalyst to assist in the regeneration of the filter. Catalyst technology, however, requires an exhaust temperature of approximately 400˚C to be effective. Small diesel engines rarely achieve this exhaust temperature, except at high loads indicative of high-speed vehicle operation, requiring adjustments to engine operating conditions or the use of fuel additives.



Above: The new ceramic fiber particulate trap employs an efficient, microwave heating cycle to regenerate itself.

Right: Flat pleated filter cartridge. The pleated design is useful for any type of regeneration system.



Since 1997, research carried out at Industrial Ceramic Solutions (ICS), located in Oak Ridge, TN, has focused on finding a more effective means of regenerating a particulate filter at low exhaust temperatures. The technology uses a microwave-sensitive silicon carbide fiber technology that enables a ceramic fiber particulate trap to be cleaned by microwaves. The fiber is incorporated into a pleated cartridge and microwave regeneration system that is connected to a microwave power source. The Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy has been sponsoring the development of this filter at ICS for the past five years. This support, along with DOE's exposure of the technology to the automotive industry, has been the driving force in moving the microwave filter toward commercialization.

Recently, it was discovered that the pleated fiber filter cartridge is

a valuable end-product capable of being used in other diesel particulate filter (DPF) regeneration systems, competing directly with all wall-flow extruded ceramic filter cartridges. The last two years of DOE funding have focused on the development of the round pleated filter cartridge.

Diesel engine manufacturers require 95% PM destruction, necessary to comply with EPA Tier 2 regulations. The ICS filter has been tested on stationary diesel engines at Ford, Oak Ridge National Laboratory, and the University of Tennessee, where test data have shown a particulate removal efficiency greater than 95% across a spectrum of normal engine operating conditions.

The Technology

The Microwave-Cleaned Ceramic Filter System utilizes a ceramic fiber pleated cartridge that contains the patented silicon carbide fibers that convert microwave energy to thermal energy at nearly 100% efficiency. The microwave-powered cleaning cycle requires only a few minutes to achieve combustion of the PM. This combustion restores the filter to its fresh condition for the next filtration cycle. The system can achieve combustion during urban driving, idle, or cold start conditions and is a solution to the low-temperature urban driving cycle where catalyst technologies are ineffective. It may also be a solution to the cold-start issue that is responsible for a significant portion of both diesel and gasoline engine emissions.

The microwave electronics and controls are isolated from the harsh exhaust stream environment, and sensors can be installed to monitor for microwave leakage. Overall, the system helps reduce the impact of particulate reduction on fuel economy to about 1%, significantly less than other types of filter regeneration systems.

Commercialization

ICS is preparing to distribute pleated DPF cartridges for original equipment manufacturer (OEM) testing in 2006. Since all of the product applications require high-volume production, component development was conducted on commercial-scale manufacturing equipment. Having completed four road tests, ICS is in the process of completing an agreement with a major automotive supplier to manufacture and distribute both the round and the flat pleated filter cartridges. It is anticipated that the pleated filter cartridges will be available for high-volume OEM vehicle use in 2008. The microwave regeneration system will be an option for high-volume applications in 2009 through a licensing agreement with a large microwave systems manufacturer.

Benefits

- Regenerates at exhaust temperatures below 300˚C.
- Filter backpressure is 5 times less than extruded honeycomb and increases at a much slower rate.
- Fuel penalty is negligible compared with other filter regeneration technologies.
- Regeneration is independent of fuel or engine operating conditions.
- Pleated filter cartridge design is suitable for large exhaust flows.
- System is compatible with planned NO_X and hydrocarbon control components.

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